Boundaries of the TTL identified by the O_3-H_2O Relationship

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Scientific Issues

- Application of the tracer-tracer correlation

  Tracer-tracer correlation technique has been used to identify the region of change in chemical characteristics, or the chemical transition layer between the troposphere and stratosphere in mid to high latitudes. How would the method work in the tropics?

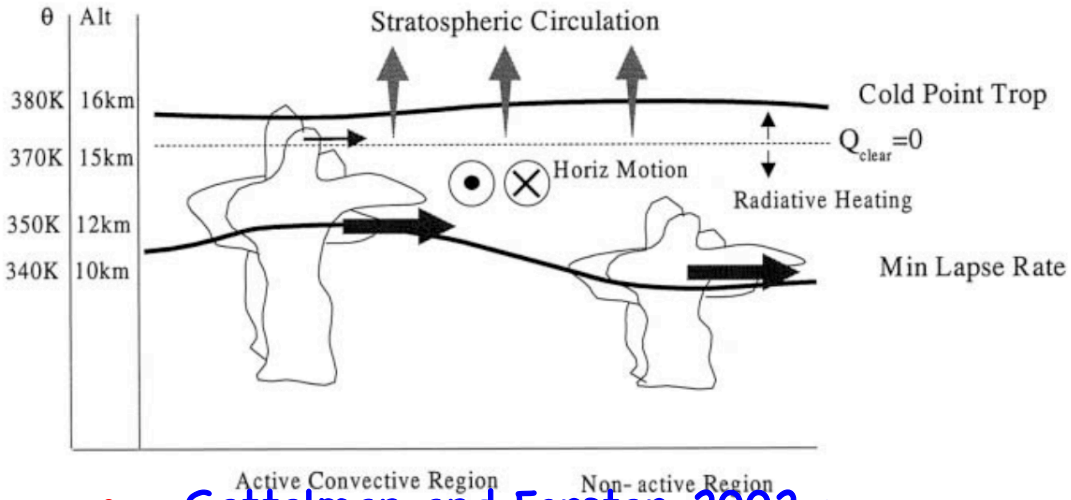
- Boundaries of the TTL

  The upper and lower boundaries of the TTL have been identified using thermal and dynamical field. How consistent are the trace gas signatures with the known dynamic boundaries?

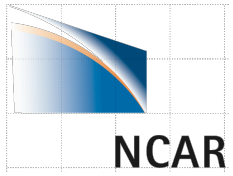
- ASM vs TTL

  Asian monsoon region has been known to behave similarly to the TTL in its very high convectively driven tropopause. How is the transition in this region similar or different from that of TTL?

Different Perspectives of the TTL Boundaries



- Gettelman and Forster, 2002 ;
  - LB: level of min stability or main convective outflow (10-12 km, ~345K)
  - UB: cold point (16-17 km)
- Fu et al., 2007 – Fueglistaler et al. 2009
  - LB: level of zero net radiative heating (14.5-15 km)
  - UB: level of upwelling mass flux decreased to the B-D (18.7 km or 70 hPa)

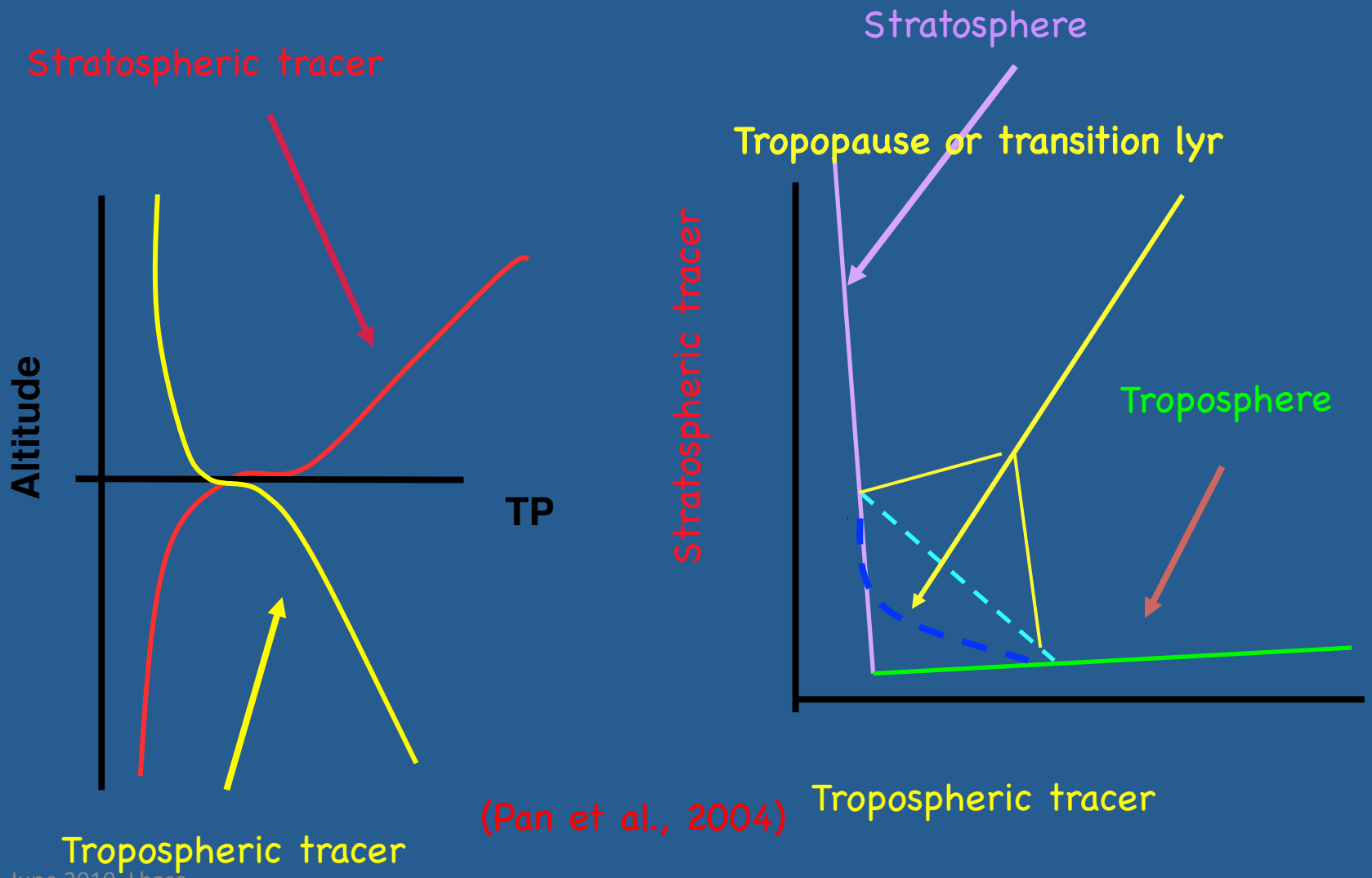


A Brief Review

the use of Tracer-Tracer correlation in characterizing transport boundaries

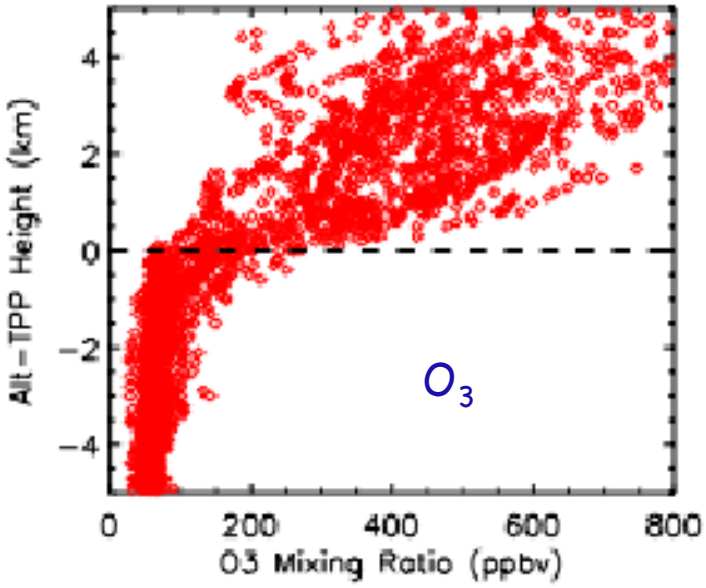
Pan et al., 2004, 2007a,b

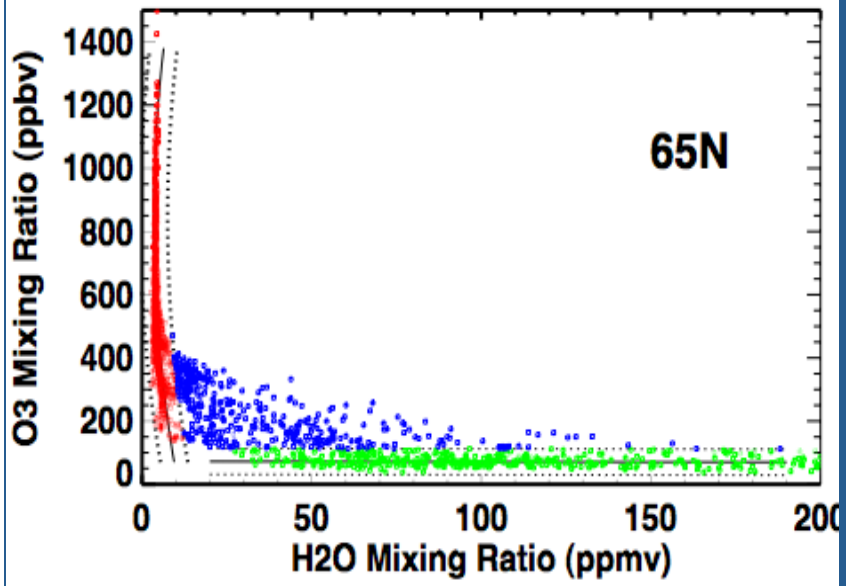
Tracer-Tracer Correlations

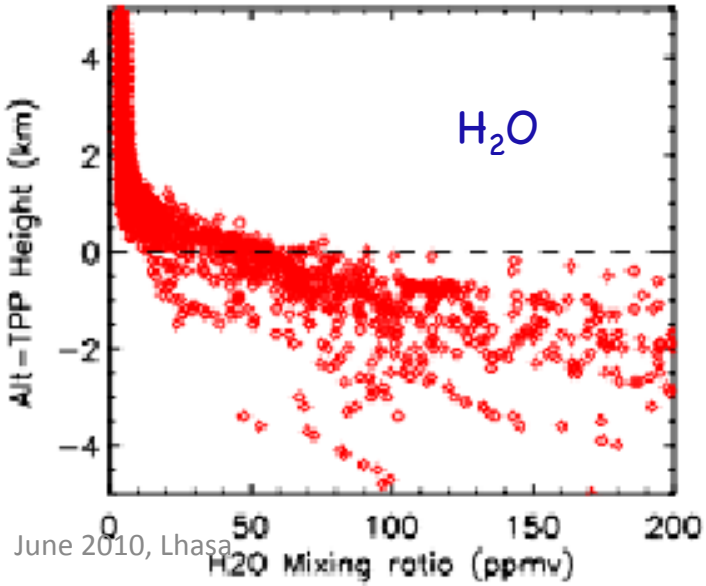


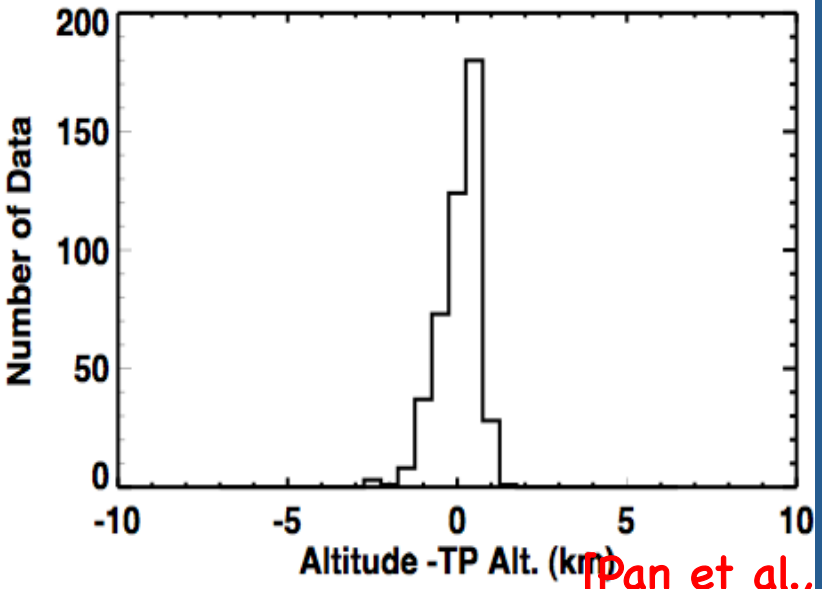
(Pan et al., 2004)

ER-2 data O_3-H_2O (POLARIS)



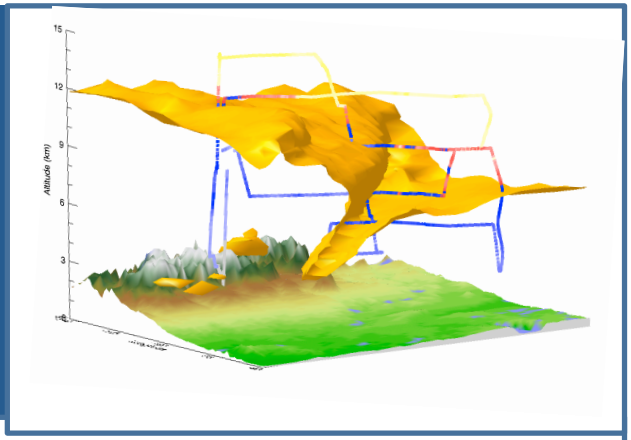


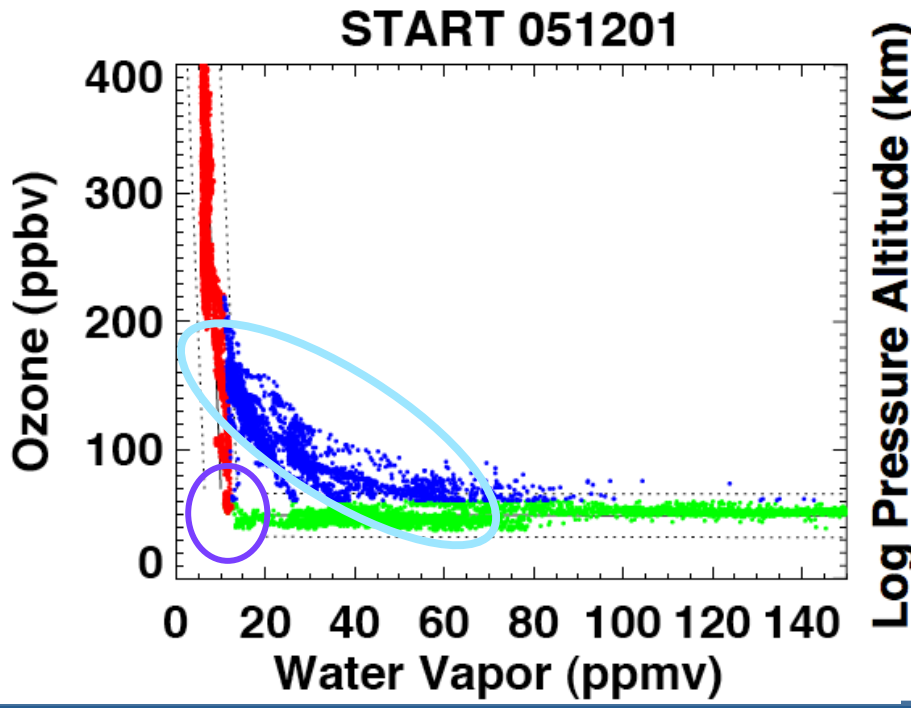


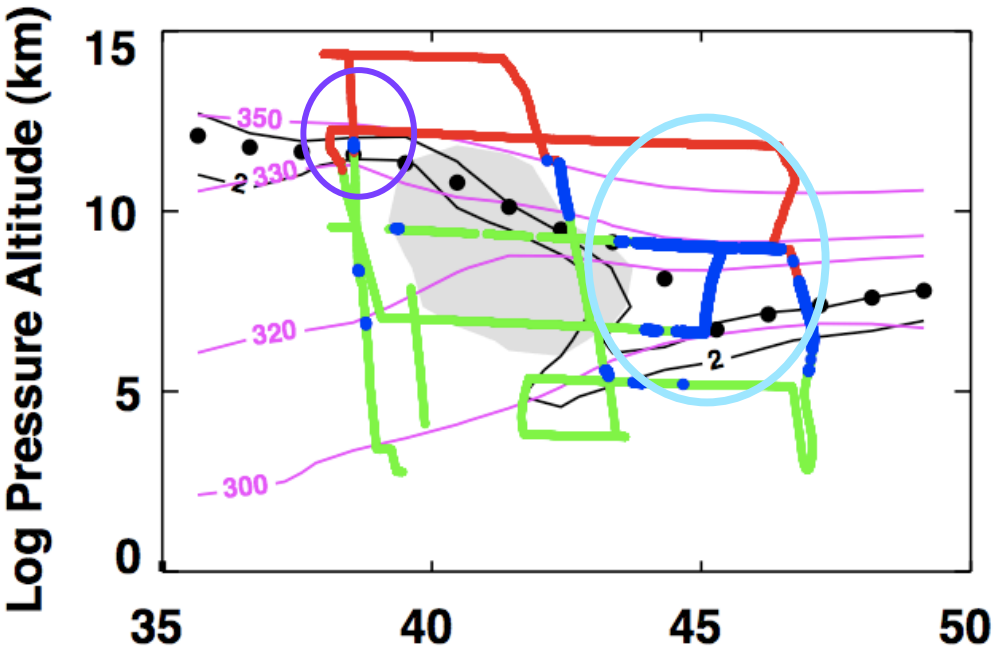


[Pan et al., 2007]

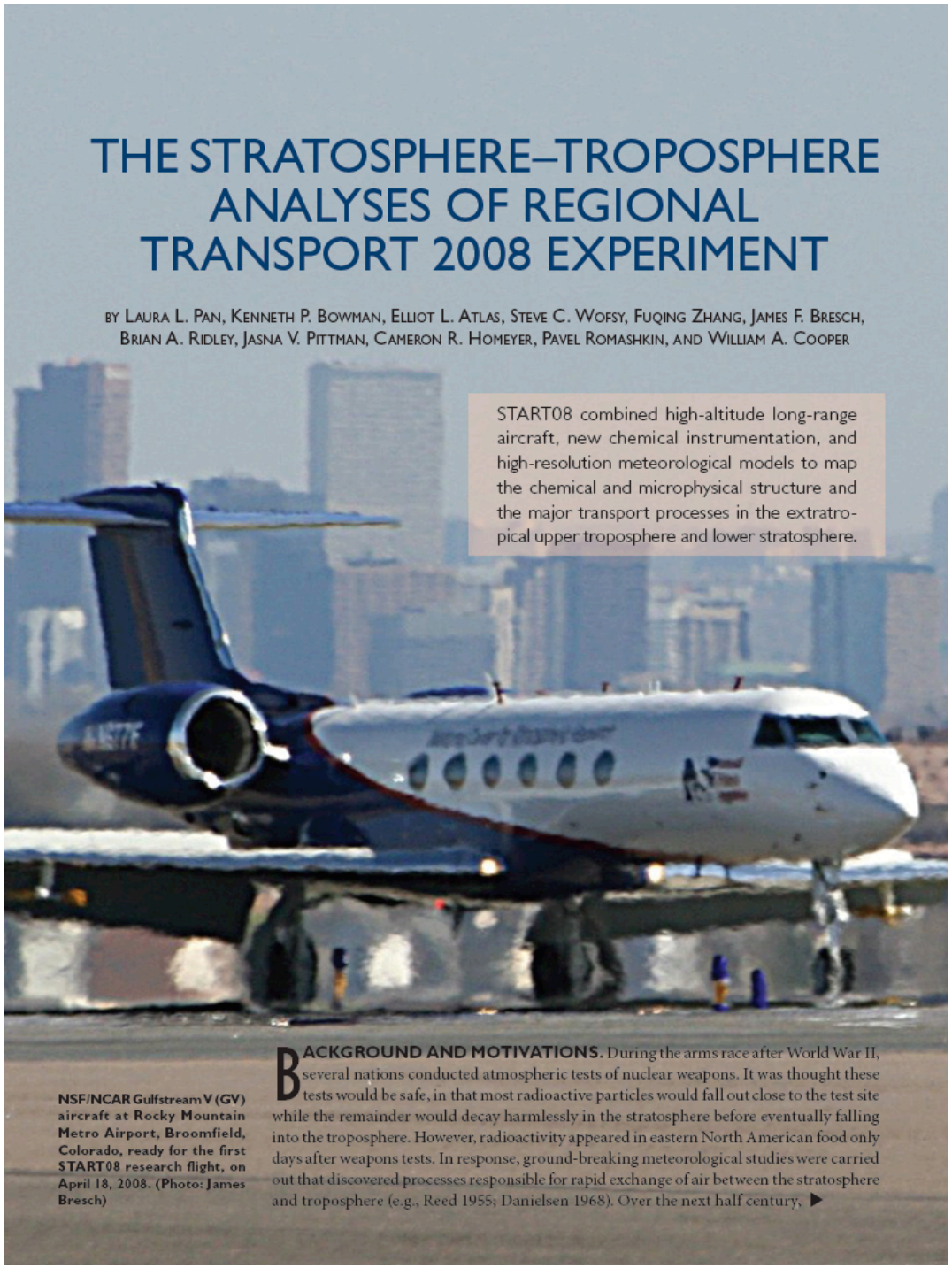
Similar results from START05 using O_3–H_2O







Pan et al., 2007



THE STRATOSPHERE–TROPOSPHERE ANALYSES OF REGIONAL TRANSPORT 2008 EXPERIMENT

BY LAURA L. PAN, KENNETH P. BOWMAN, ELLIOT L. ATLAS, STEVE C. WOFSY, FUQING ZHANG, JAMES F. BRESCH, BRIAN A. RIDLEY, JASNA V. PITTMAN, CAMERON R. HOMEYER, PAVEL ROMASHKIN, AND WILLIAM A. COOPER

START08 combined high-altitude long-range aircraft, new chemical instrumentation, and high-resolution meteorological models to map the chemical and microphysical structure and the major transport processes in the extratropical upper troposphere and lower stratosphere.

NSF/NCAR Gulfstream V (GV) aircraft at Rocky Mountain Metro Airport, Broomfield, Colorado, ready for the first START08 research flight, on April 18, 2008. (Photo: James Bresch)

BACKGROUND AND MOTIVATIONS. During the arms race after World War II, several nations conducted atmospheric tests of nuclear weapons. It was thought these tests would be safe, in that most radioactive particles would fall out close to the test site while the remainder would decay harmlessly in the stratosphere before eventually falling into the troposphere. However, radioactivity appeared in eastern North American food only days after weapons tests. In response, ground-breaking meteorological studies were carried out that discovered processes responsible for rapid exchange of air between the stratosphere and troposphere (e.g., Reed 1955; Danielsen 1968). Over the next half century, ▶

START08 Campaign

- **April – June, 2008 operated from Colorado (RAF)**
- **Participated by NCAR, TAMU, Univ. Miami, Univ. Colorado, Harvard U., and NOAA**

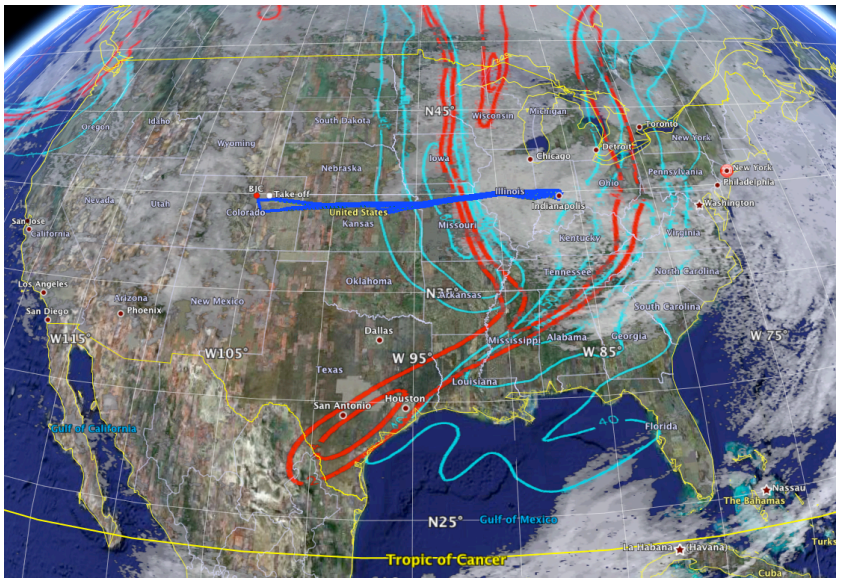
Principal Investigators:

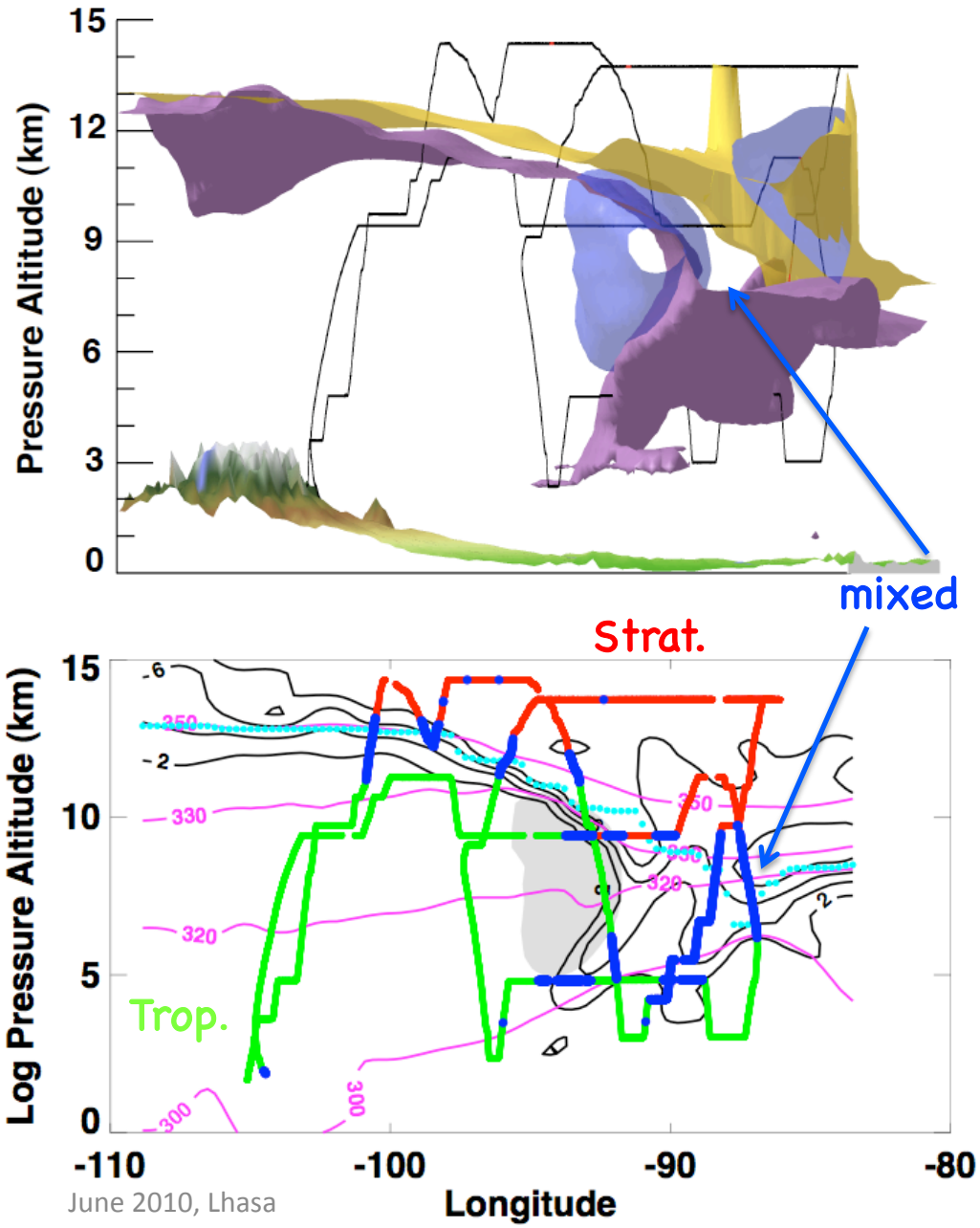
Laura Pan, Elliot Atlas (Miami U), Kenneth Bowman (TAMU)

Pan et al., BAMS, March 2010 issue

START08 using O_3-CO

RF04, April 28, 2008

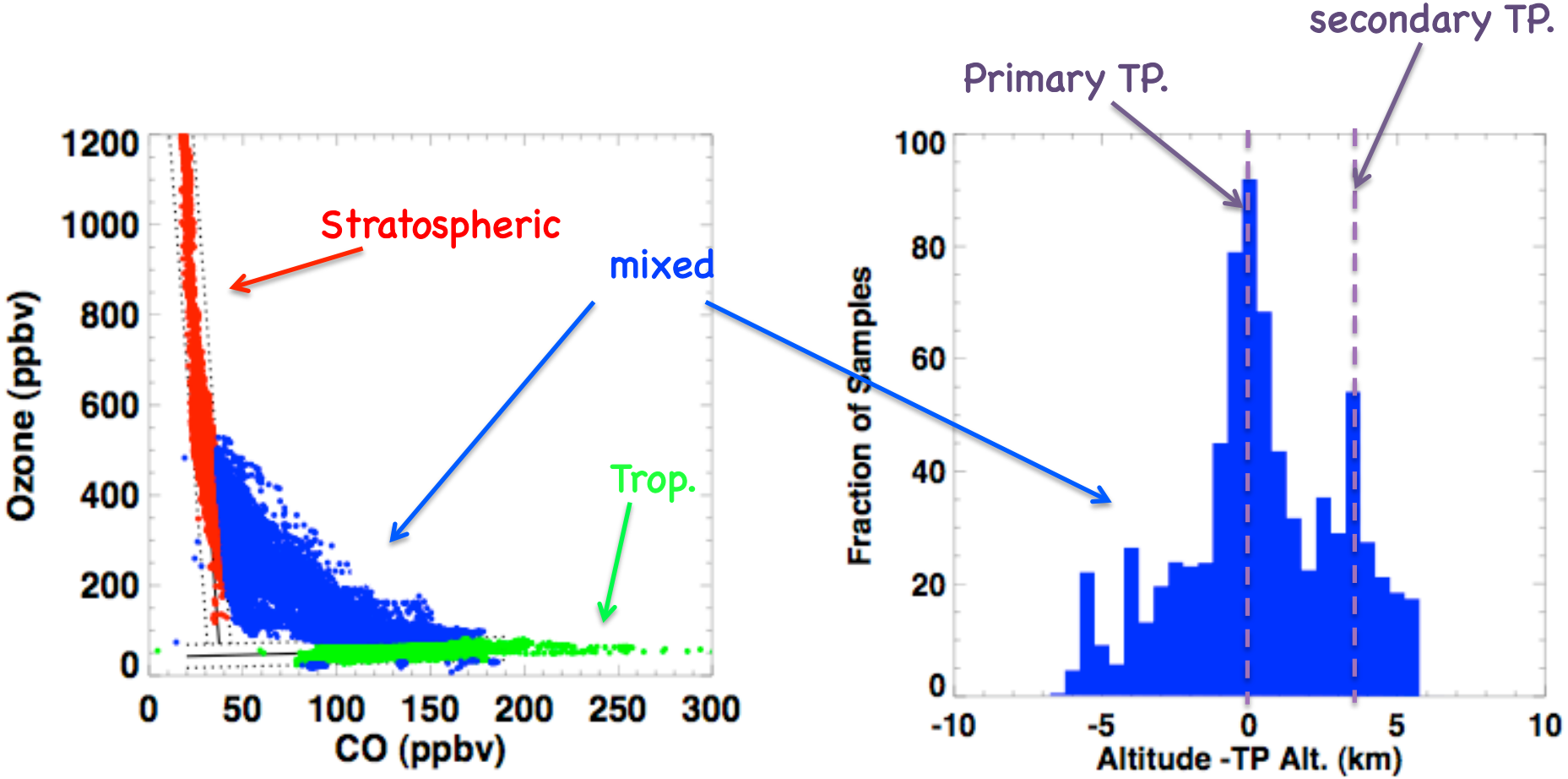




Pan et al., 2010

Tracer Correlation – Mixing – ExTL, and Transport Pathways

Vertical profiles from 12 flights April-May, the thermal tropopause is determined from the T profile of GV in situ measurements



Issues of using a/c data in Tropics

- Vertical ranges of a/c data are usually limited to near the top of TTL
- which make the identification of Stratospheric background somewhat subjective
- CFH and ozonesonde data (up to almost 30 km) are used here to demonstrate the concept
- The use of other tracers will be investigated

Cryogenic Frost Point Hygrometer (CFH) and ECC ozonesonde data

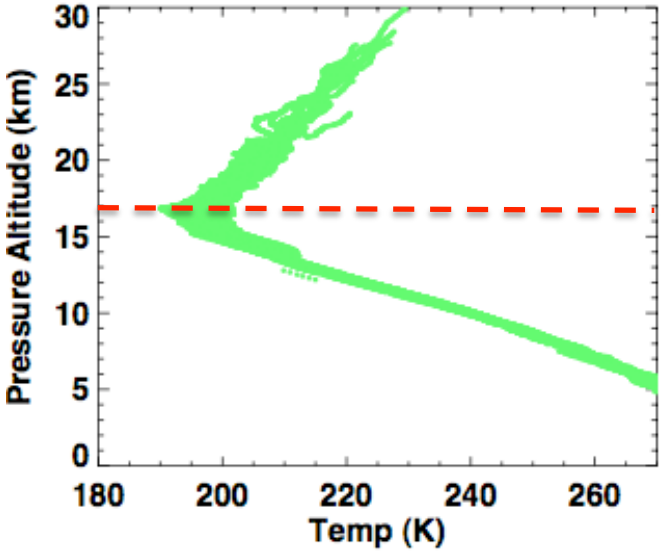
- Upgraded version of NOAA FPH
- Total uncertainty of the CFH:
  - Tropical: 3%–5% in the lower-to-middle troposphere,
  - 5%–8% in the upper troposphere and in the
  - 133 TTL,
  - and 8%–9.5% in the lower stratosphere up to 28 km altitude

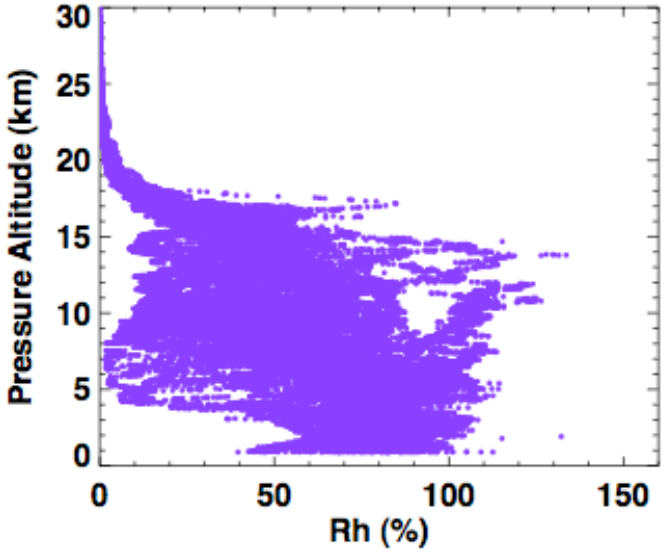
Vömel et al., 2007, Fujiwara et al., 2010

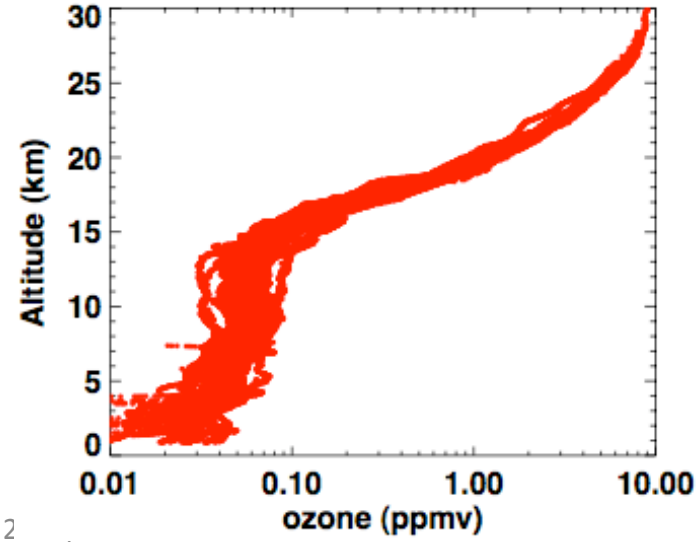
Campaigns: TCSP, TC4 and Asian Monsoon (KunMing)

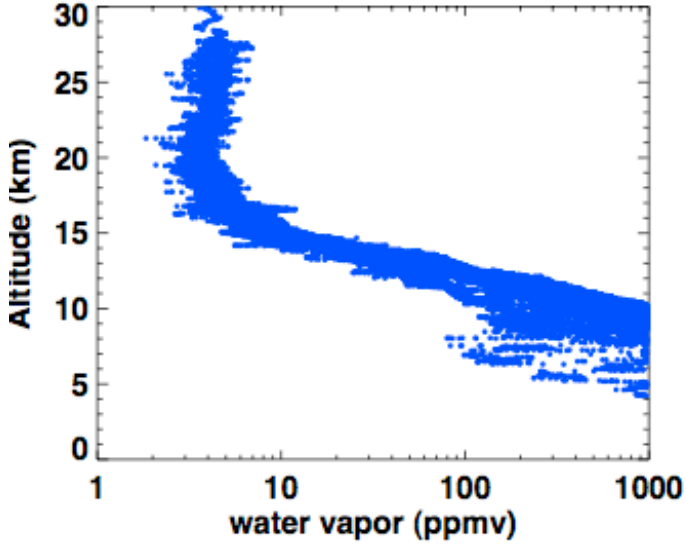
- **TCSP**
  - July 2005
  - Alajuela, Costa Rico (10°N, 84.2°W)
  - 24 profiles
- **TC4**
  - July-August 2007
  - Alajuela, Costa Rico (10°N, 84.2°W)
  - 16 profiles
- **Asian Monsoon Study**
  - August 2009
  - KunMing, China (25°N, 102°E)
  - 11 profiles

TC4 data – 16 profiles

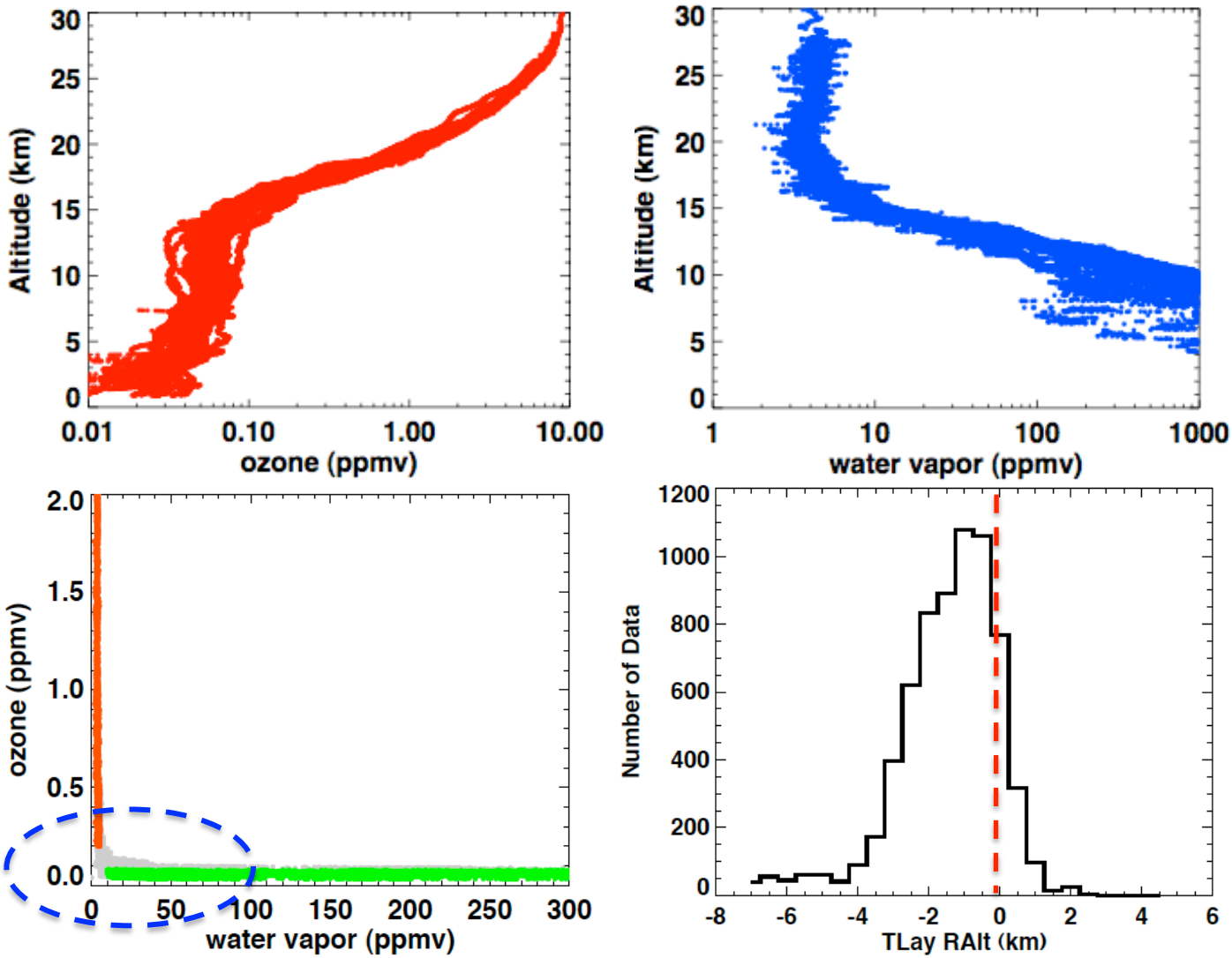




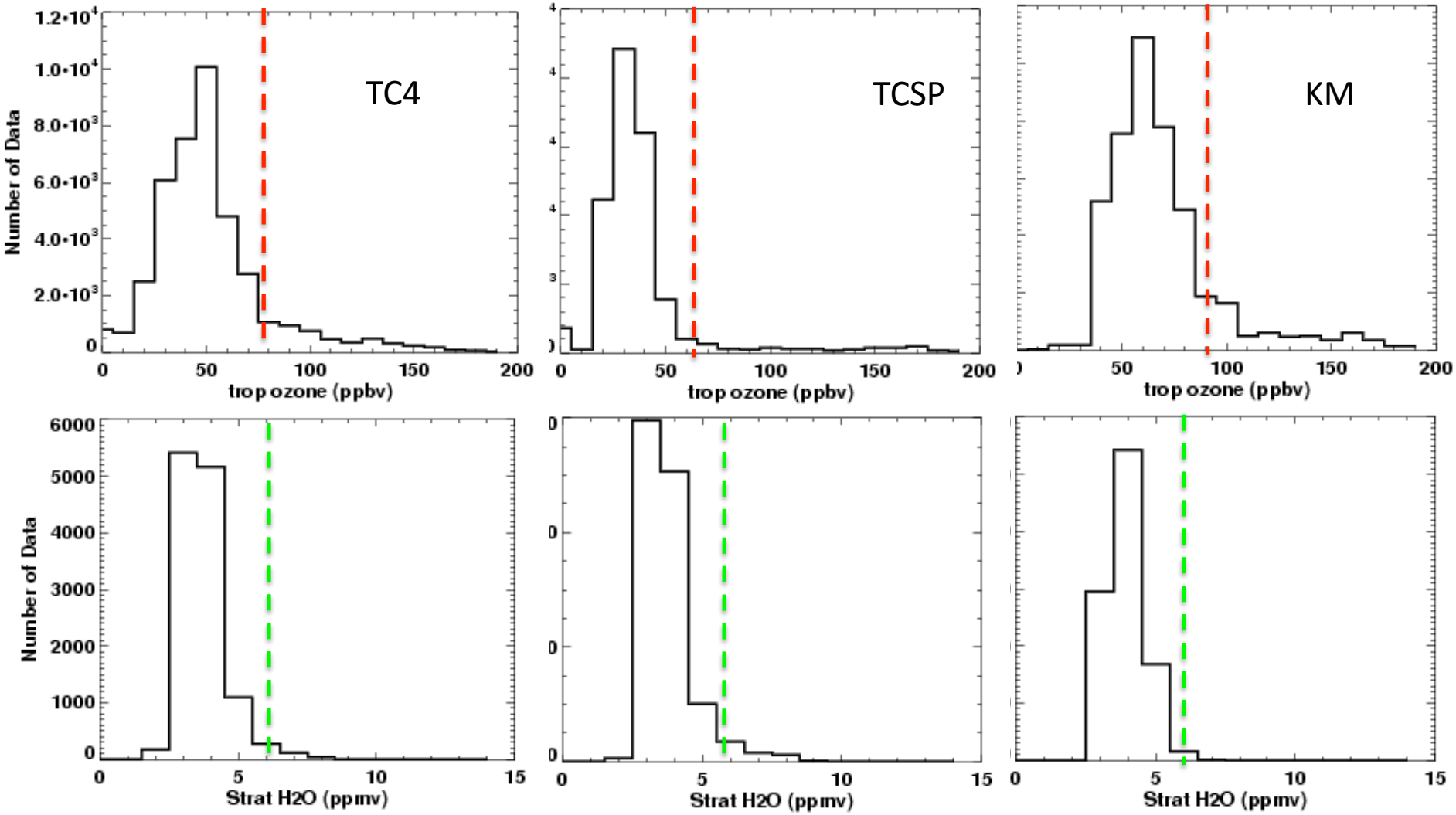




TC4 data – Example of the Transition Layer

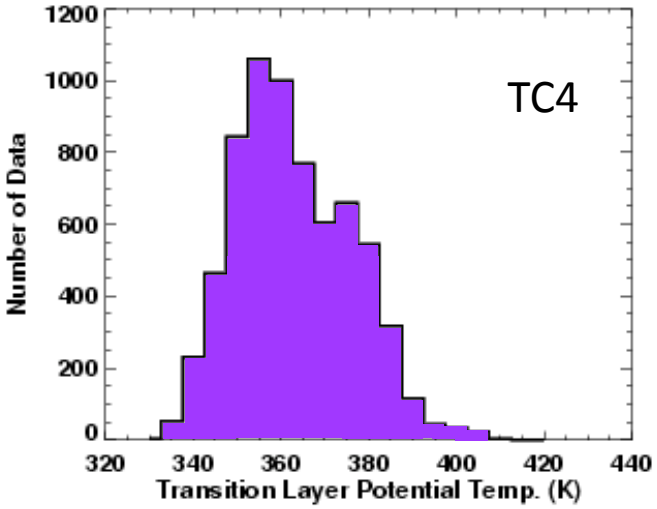


Determination of the Strat./Trop. background

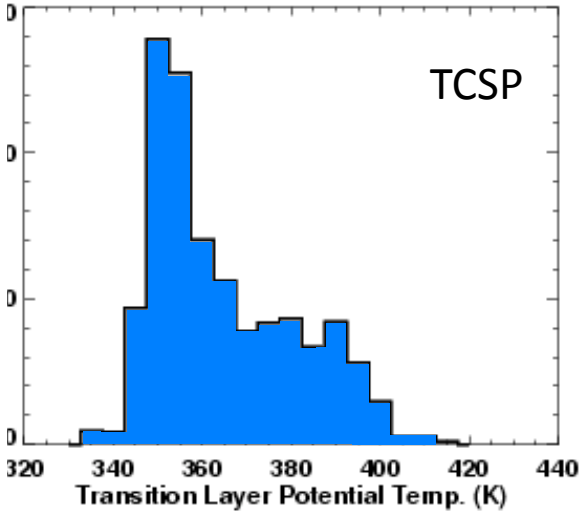


Transition Layer Depth in Potential Temperature

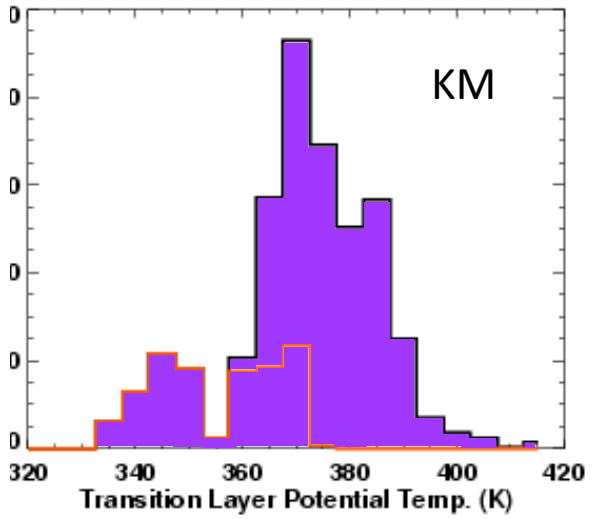
345-390 K

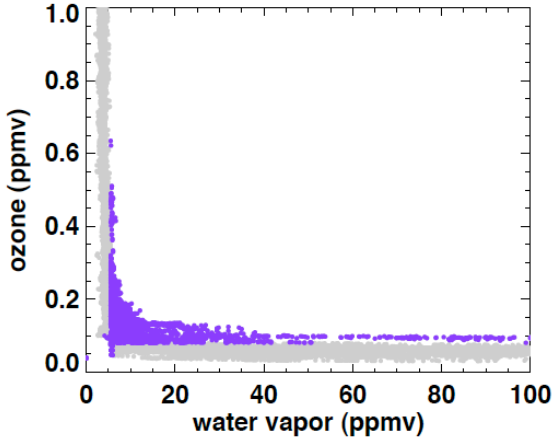


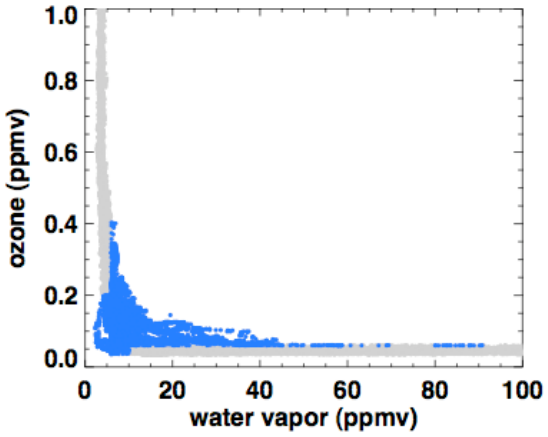
345-395 K

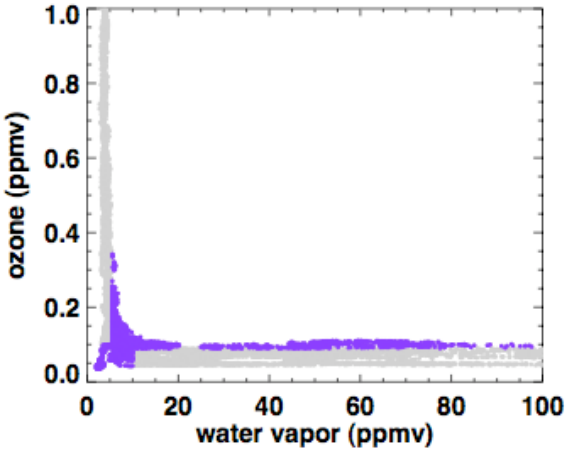


365-395 K









Relating the transition layer to the dynamic boundaries:

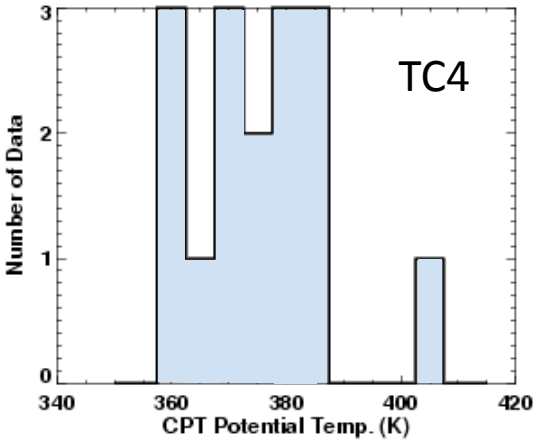
Cold Point tropopause

and

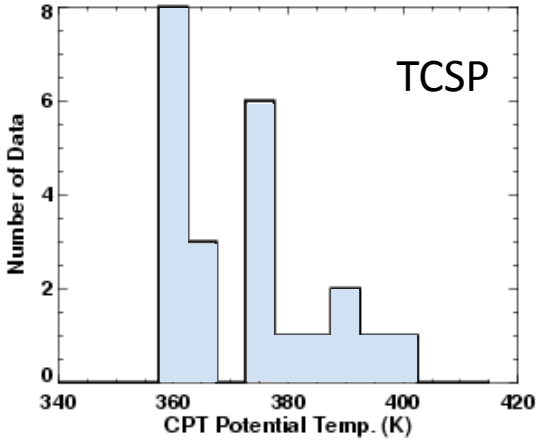
the level of Neutral/minimum Stability

Cold Point Potential Temperature and Height

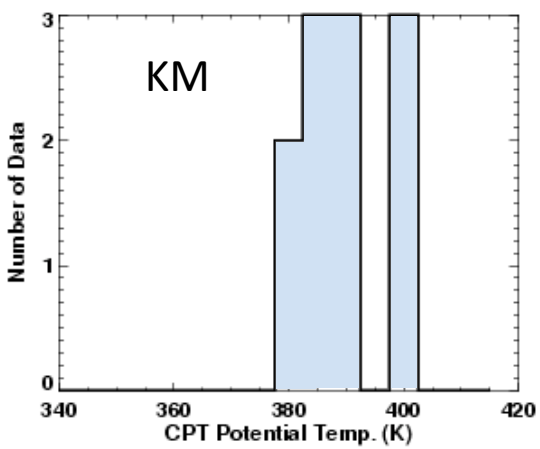
360-390 K

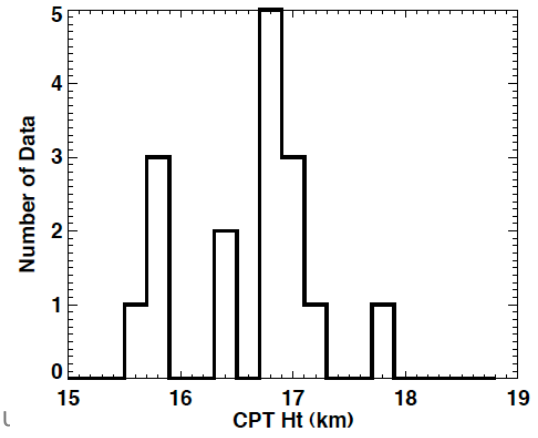


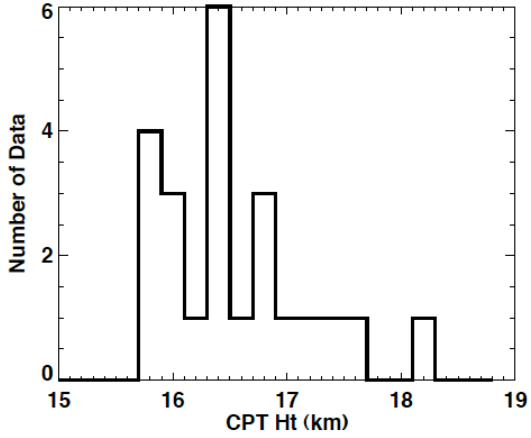
360-400 K

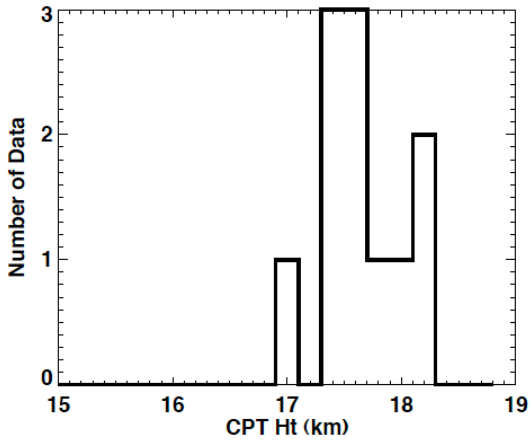


380-400 K









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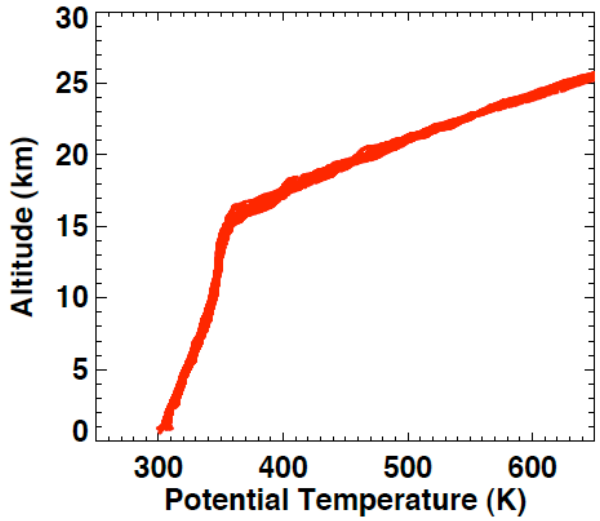
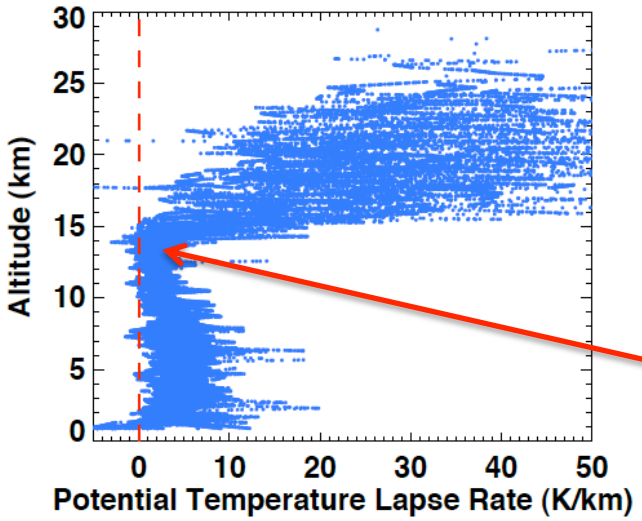
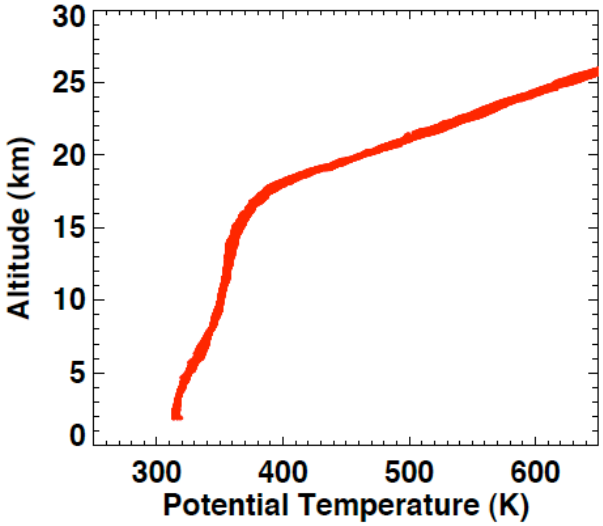
Potential Temperature Profiles and the Lapse Rate

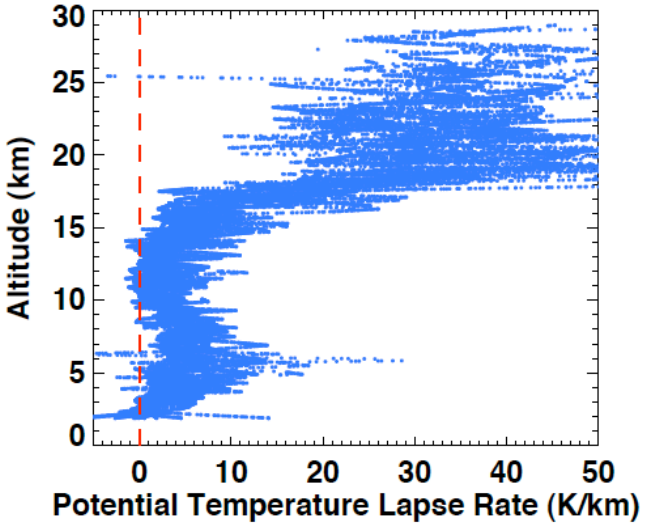




TC4

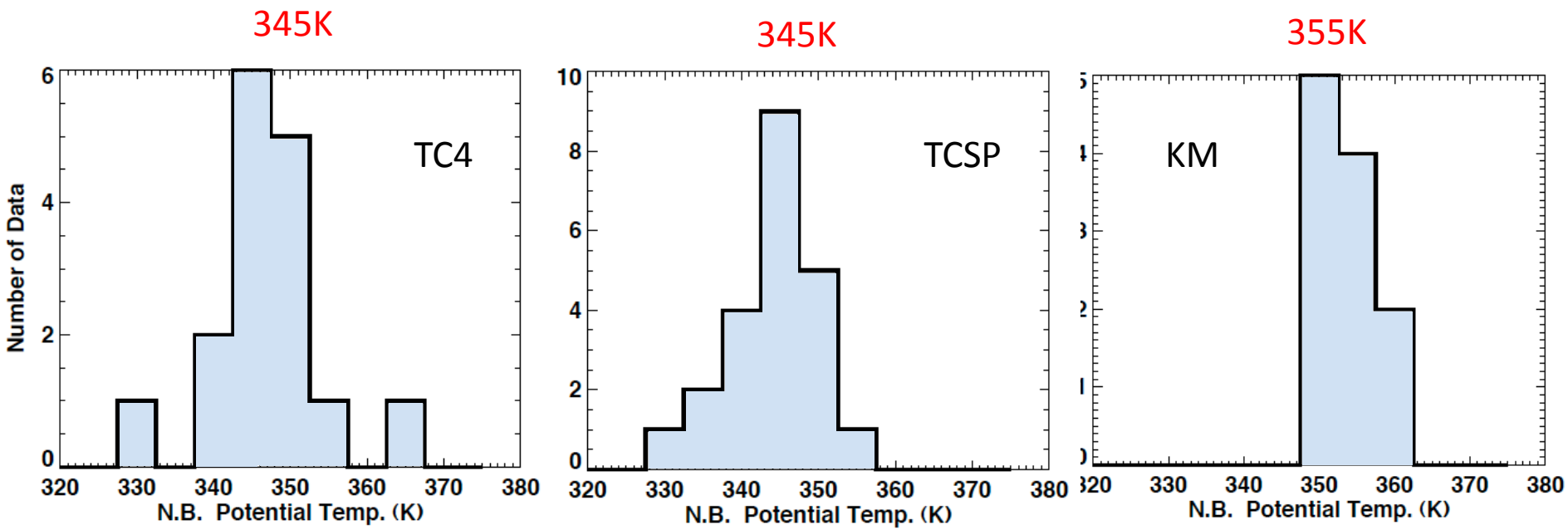
"Level of minimum Stability" or "neutral stability"



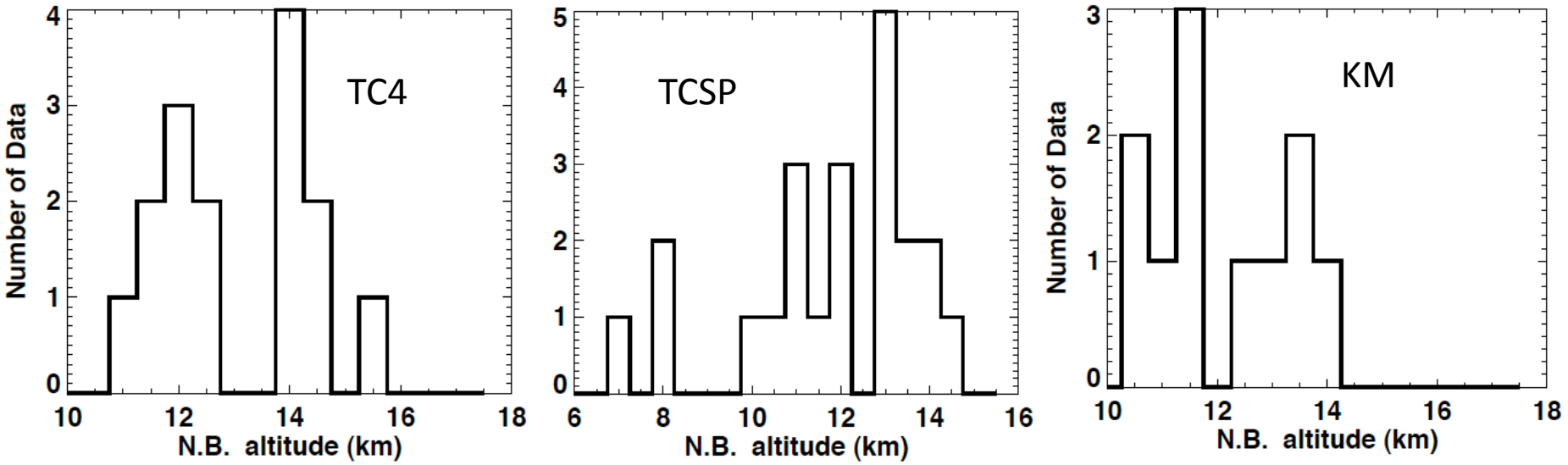


KM

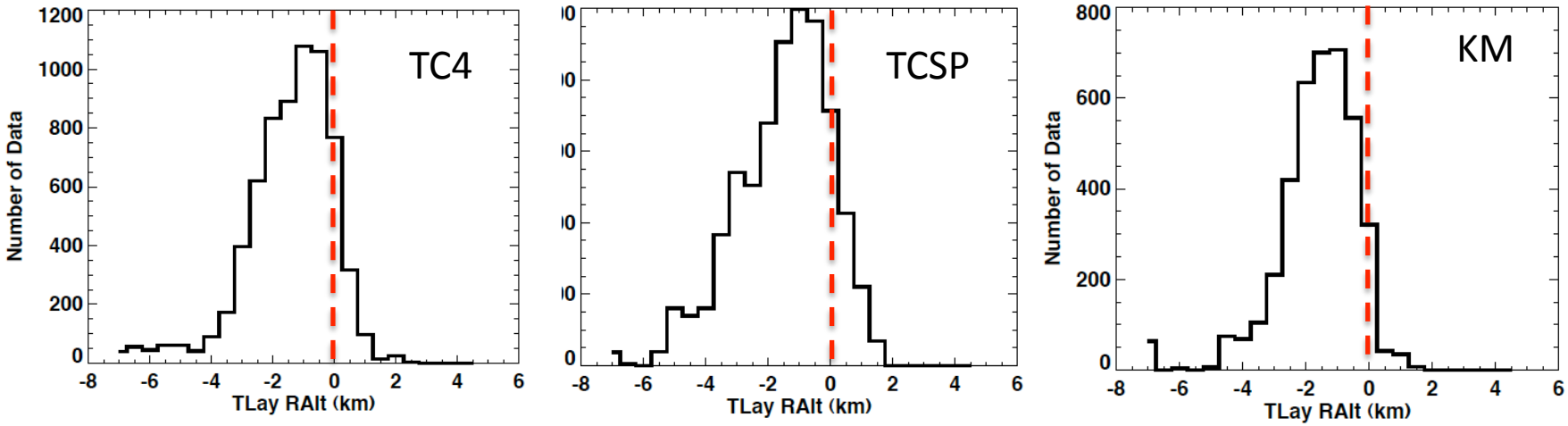
Neutral/Minimum Stability Potential Temperature



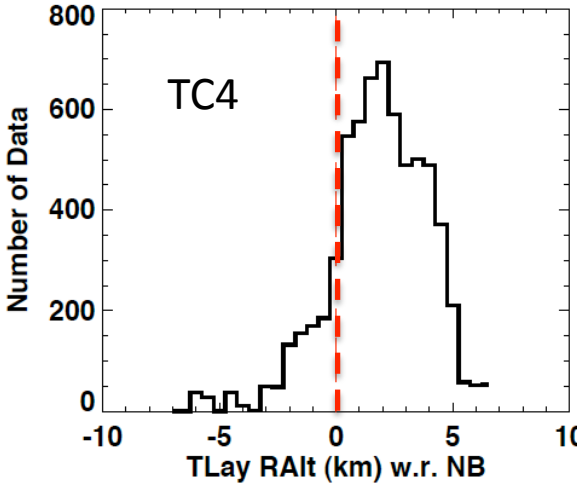
Minimum Stability Height

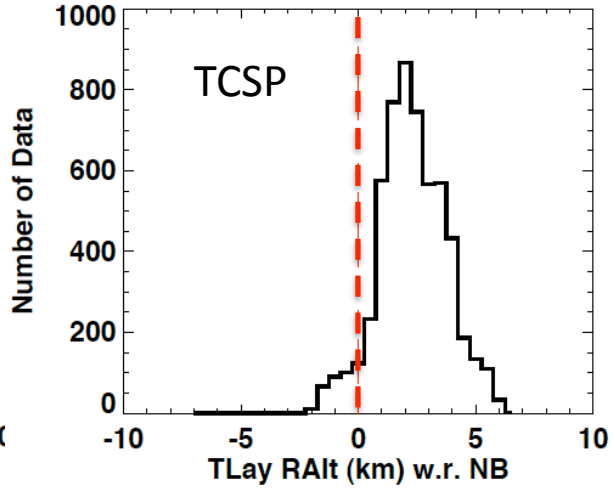


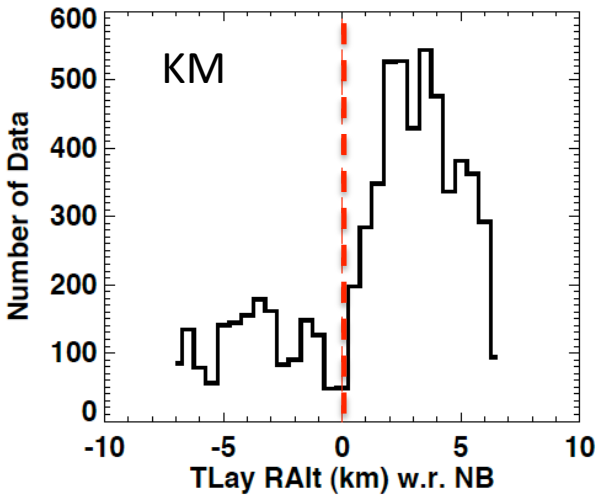
Transition Layer Relative to the Cold Point Tropopause

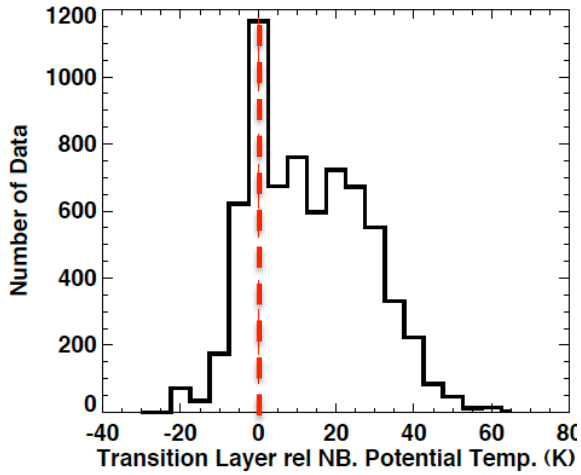


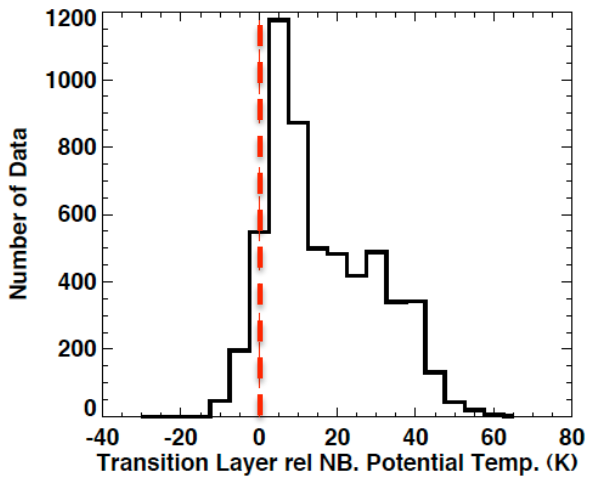
Transition Layer Relative to the Level of Minimum Stability

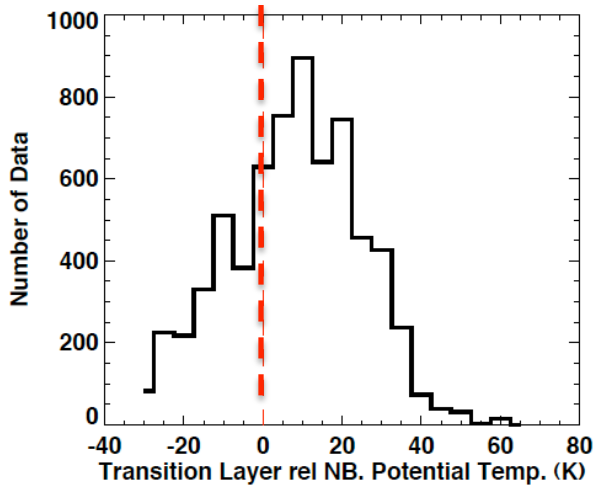








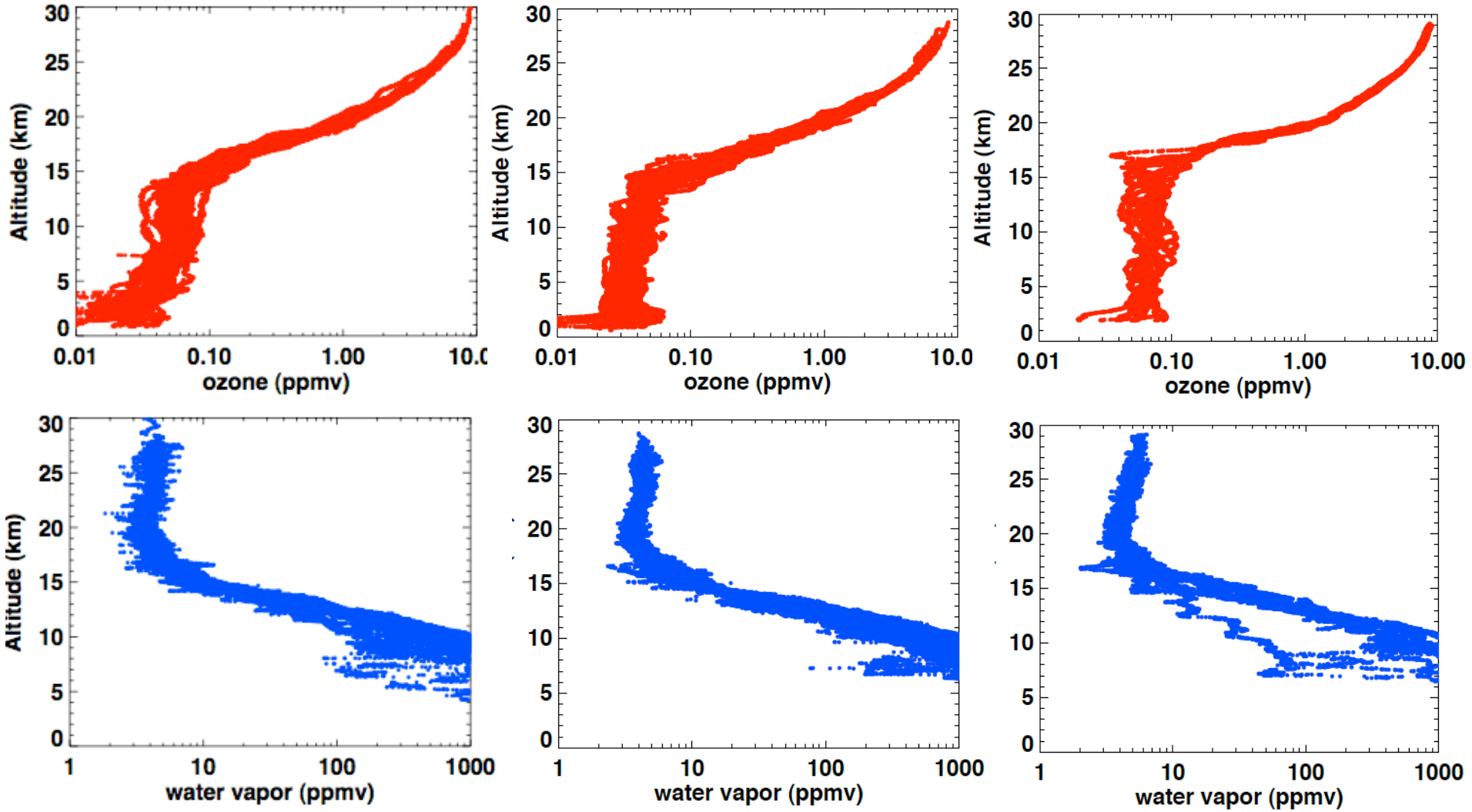




Summary and Conclusions

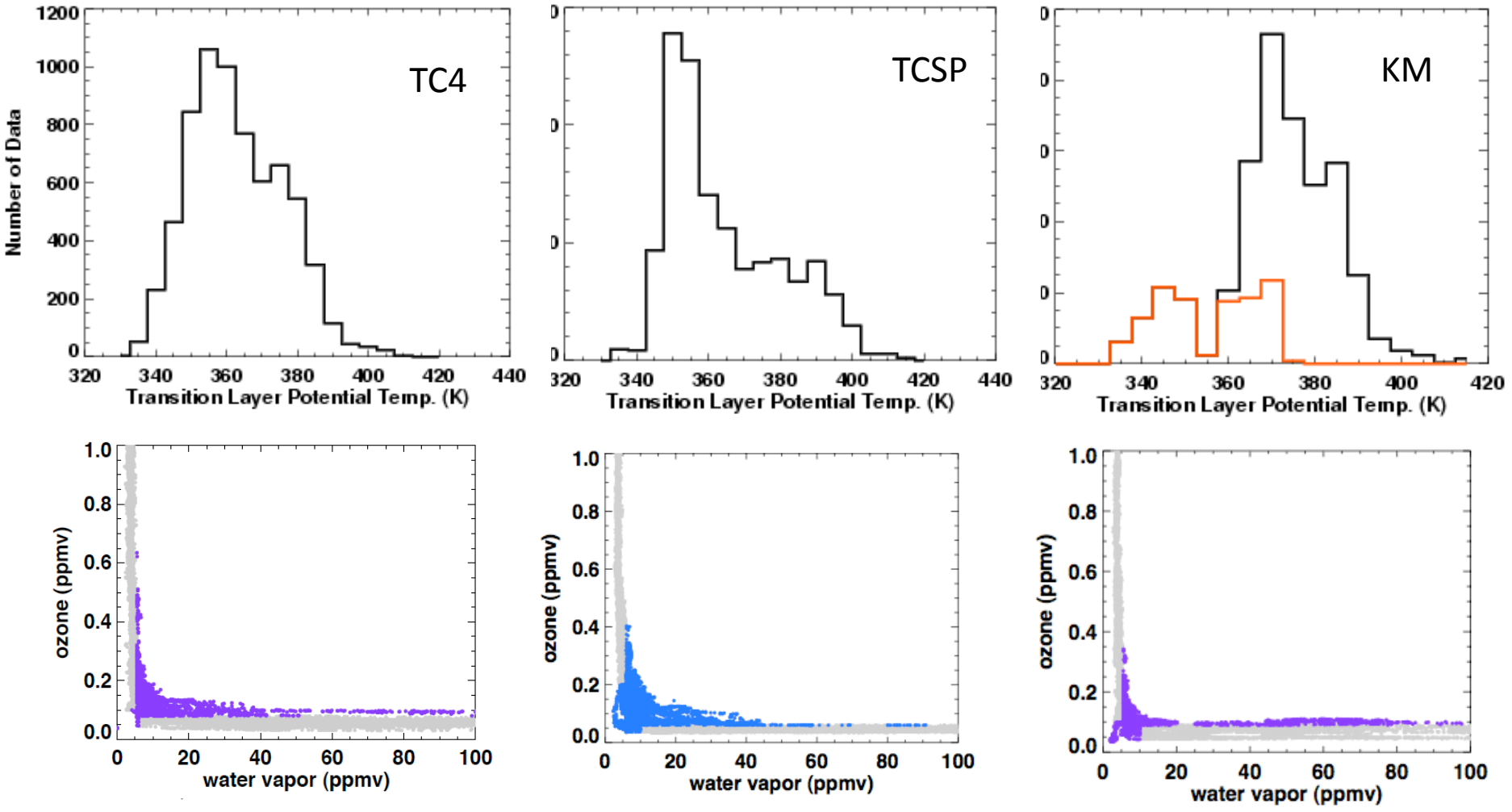
- Simple measurements of Ozone and water vapor can provide key characterization of the UTLS – troposphere to stratosphere transition in particular
- O_3–H_2O Tracer–Tracer correlation characterization of TTL:
  - Depth: ~345–390K, ~ 4 km mostly below the cold point tropopause
  - Confirms: Upper bound by the cold point tropopause, lower bound by the level of minimum stability (near neutral stability)
- The tropospheric to stratosphere transition in the Asian Monsoon region show similarity and differences from TTL
  - Smaller depth, higher PT range for both lower and upper boundaries, and with lower C.P. temperatures

TC4 (CR)
16 profiles

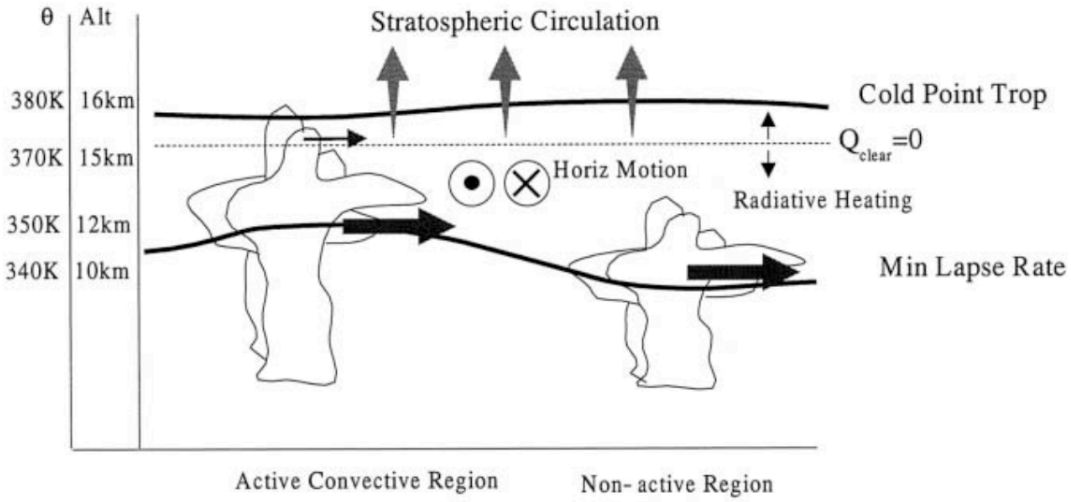


Laura Pan, June 2010

Transition Layer Depth in Potential Temperature



Indication of Dynamical Boundaries: ExTL vs TTL



Gettelman and Forster, 2002

TTL : A layer with two boundaries

BIRNER: EXTRATROPIC/

ExTL: a single boundary

Birner, 2006